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[Title of the Invention] LIQUID CRYSTAL CELL

[Abstract]

[Object] To provide a liquid crystal cell which can damp a vacuum generated between two electrode substrates as a result of the volume shrinkage of a liquid crystal having a high viscosity at the room temperature by communicating between two of a plurality of filling portions formed between two electrode substrates by a plurality of barrier walls through the intervening barrier walls.

[Solving Means] Each of the recess formed on an orientation film 26 of an upper electrode substrate 20, corresponding to the region between each adjacent pair of the two color filter layers of a plurality of color filter layers 22 formed on the upper electrode substrate 20, is formed as a through hole 41 which communicates each adjacent pair of the two filling portions from a plurality of filling portions 50 located between each barrier wall 40.

[Claims]

[Claim 1] A liquid crystal cell comprising:

two electrode substrates 10 and 20;

a band seal 20a interposed between the electrode substrates at the peripheral edges thereof;

a plurality of barrier walls 40 clamped in parallel to

and disposed apart from each other between the two electrode substrates at the inner peripheral side of the seal to form a plurality of filling portions 50; and

a liquid crystal 30 filled in each filling portion between the two electrode substrates through the seal,

wherein through holes 41 and 44 of the plurality of barrier walls are formed to communicates each adjacent pair of the two filling portions of a plurality of filling portions.

[Claim 2] The liquid crystal cell according to claim 1, wherein the individual through holes are formed in individual barrier walls around the inner wall of one of the two electrode substrates.

[Claim 3] A liquid crystal cell comprising:

two electrode substrates 10 and 20;

a band seal 20a interposed between the electrode substrates at the peripheral edges thereof;

a plurality of barrier walls 40 clamped in parallel to and disposed apart from each other between the two electrode substrates at the inner peripheral side of the seal to form a plurality of filling portions 50; and

a liquid crystal 30 filled in each filling portion between the two electrode substrates through the seal,

wherein each of the plurality of barrier walls is made of a single material and has a lower rigidity in at least

one portion of each barrier wall than that of other portions of each the barrier wall.

[Claim 4] The liquid crystal cell according to any one of claims 1 to 3, wherein the liquid crystal is a smectic liquid crystal and the individual through holes are formed to damp the vacuums in a plurality of filling portions caused by the volume shrinkage of a smectic liquid crystal.

[Claim 5] The liquid crystal cell according to any one of claims 1 to 3, wherein the liquid crystal is a smectic liquid crystal and when the smectic liquid crystal is filled up, a plurality of through holes have an opening shape to prevent the disturbance and stagnation of the flow of liquid crystal flowing to the individual through holes.

[Claim 6] The liquid crystal cell according to any one of claims 1 to 5, wherein at least one of the two electrode substrates is provided with orientation films 14 and 26 which are oriented in a one-axis direction as an inner surface thereof; and

a plurality of barrier walls are extended to a one axis orientation direction of the orientation films between the two electrode substrates.

[Claim 7] A liquid crystal cell comprising:

a first electrode substrate 10;

a second electrode substrate 20 which is opposite to the first electrode substrate and in which a plurality of

color filter layers 22 and a plurality of black mask layers 23 are alternatively arranged;

a band seal 20a interposed between the first electrode substrate and the second electrode substrate at the peripheral edges thereof;

a plurality of barrier walls 40 clamped between the first electrode substrate and the second electrode substrate to be perpendicular to a plurality of color filter layers in the vicinity of the inner circumference of the seal and forming a plurality of filling portions 50 between the first electrode substrate and the second electrode substrate to be arranged apart from and parallel to each other; and

a liquid crystal 30 filled in the individual filling portions through the seal between the first electrode substrate and the second electrode substrate,

wherein the individual recesses formed in the inner wall of the second substrate corresponding to regions between the adjoining two of a plurality of color filter layers are formed as through holes 41 and 44 for communicating the adjoining two of a plurality of filling portions.

[Claim 8] The liquid crystal cell according to claim 7, wherein the liquid crystal is a smectic liquid crystal and the individual through holes are formed to damp the vacuums in a plurality of filling portions caused by the volume

shrinkage of a smectic liquid crystal.

[Claim 9] The liquid crystal cell according to claim 1, wherein the liquid crystal is a smectic liquid crystal and when the smectic liquid crystal is filled up, a plurality of through holes have an opening shape to prevent the disturbance and stagnation of the flow of liquid crystal flowing to the individual through holes.

[Claim 10] The liquid crystal cell according to any one of claims 7 to 9, wherein at least one of the first and second electrode substrates is provided with orientation films 14 and 26 which are oriented in a one-axis direction as an inner wall thereof; and

a plurality of barrier walls are extended to a one-axis orientation direction of the orientation films between the first and second electrode substrates.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a liquid crystal cell employing a liquid crystal having a high viscosity at the room temperature such as a smectic liquid crystal.

[0002]

[Description of the Related Art]

Conventionally, the liquid crystal cell is constructed by

filling up a smectic liquid crystal between two electrode substrates interposed by a band seal, a spherical spacer, and an adhesive particle. However, when the electrode substrate is deformed by a local pressure or an impact applied to the liquid crystal cell, disturbance is generated in a specific layer structure of the smectic liquid crystal. However, the disturbance is not recovered although the deformation of the electrode substrate is removed.

[0003]

In order to solve the above-mentioned problem, as disclosed in Japanese Unexamined Patent Application Publication No. H7-318912, by providing a plurality of barrier walls 4 on the inner peripheral side of the seal between the two electrode substrates (see reference numerals 1 and 2 in Fig. 9) and closely contacting the individual barrier walls 4 on the inner surface of the two electrode substrates, it is considered to enhance the resistance to vibration and shock of the liquid crystal cell and to prevent the disturbance of a layer structure of the smectic liquid crystal.

[0004]

[Problems to be Solved by the Invention]

However, In the liquid crystal cell, the phase structure of the smectic liquid crystal makes a complicated phase transition from the liquid phase (i.e., the isotropic

phase) in a high temperature state to, for example, a smectic A phase → a chiral smectic C phase → a chiral smectic CA phase, as the temperature lowers.

[0005]

According to this transition in the phase structure of the smectic liquid crystal, this smectic liquid crystal shrinks in its volume to generate a defect that bubbles are produced in the liquid crystal cell. That is, when a volume of the smectic liquid crystal shrinks, the liquid crystal cell of a structure having the plurality of barrier walls interposed between the two electrode substrates is disabled to change the space between the two electrode substrates and by the plurality of barrier walls.

[0006]

As a result, a filling portion filled with the smectic liquid crystal in the liquid crystal cell is evacuated to be negative pressure to gasify the gaseous component left in the liquid crystal cell so that the bubbles are produced. This difficulty is prominent especially when the liquid crystal cell having been filled with the smectic liquid crystal is left in a low temperature state (e.g., -20℃).

[0007]

This bubbling phenomenon will be described in more detail. The smectic liquid crystal has a high viscosity at the room temperature so that it cannot be injected as it is

into the liquid crystal cell. Therefore, the liquid crystal cell is heated to change the phase structure of the smectic liquid crystal into a liquid phase before the liquid crystal cell is filled with the smectic liquid crystal.

[0008]

After filling operation, the smectic liquid crystal is slowly cooled to the room temperature so that its orientation may be improved. However, according to this slow cooling, the volume of the smectic liquid crystal shrinks, as indicated by a "graph L" of Fig. 11. Therefore, even when the smectic liquid crystal reaches the room temperature, it is thought that the inside of the liquid crystal cell is evacuated to be negative pressure as a result of the volume shrinkage of the smectic liquid crystal.

[0009]

It would be better if the vacuum could be damped by deforming the liquid crystal cell with it, but the electrode substrates are hard to deform in the presence of the plurality of barrier walls. This makes it impossible to damp the vacuum in the liquid crystal cell so that the bubbles are produced in the liquid crystal cell. The situations in which the bubbles are produced will be described in more detail. These bubbles are linearly produced, as shown in FIGS. 9 and 10, at the individual widthwise centers of the plurality of filling portions 6 formed between the two

electrode substrates 1 and 2 by the plurality of barrier walls 4, and in the longitudinal direction of the individual filling portions.

[0010]

That is, it is thought that the linear bubbles 5 are produced at the widthwise centers of the individual filling portions 6 because the inside of the liquid crystal cell is evacuated by the volume shrinkage of the smectic liquid crystal in the individual filling portions 6 and because the excellent wettability between the smectic liquid crystal and the individual barrier walls made of a proper material establishes a force to attract the smectic liquid crystal toward the individual barrier walls.

[0011]

Thus, in the display area of the liquid crystal cell, a linear display occurs due to each of the linear bubbles 5. As a countermeasure against the aforementioned bubble production, it is conceivable to enhance the filling density of the liquid crystal cell with the smectic liquid crystal. This concept is exemplified by a method of filling the liquid crystal cell with the smectic liquid crystal by a pressure, as disclosed in Japanese Unexamined Patent Application Publication No. H6-67136. However, this disclosure has been insufficient for preventing the bubble production.

[0012]

This point will be described in detail. The bubbles which are the unfilled regions of the smectic liquid crystal are surely reduced at the room temperature, but the liquid crystal cell may be used at 0℃ or lower. Therefore, if the liquid crystal cell is exposed to this low temperature circumstance, the volume of the smectic liquid crystal further shrinks, as indicated by the graph L in Fig. 11, so that the inside of the liquid crystal cell is evacuated to be negative pressure. This evacuation is thought to produce the linear bubbles in the liquid crystal cell. Moreover, the bubbles thus once produced do not disappear but remain even if the temperature of the liquid crystal cell is returned to the room temperature, to cause the display defect in the display area (i.e., the area enclosed by single-dotted lines in Fig. 9) of the liquid crystal cell.

[0013]

The present invention is to solve the above-mentioned problem, and an object of the present invention is to provide a method of manufacturing a liquid crystal display panel capable of enhancing the panel display at the periphery of the display portion.

[0014]

[Means for Solving the Problems]

In order to achieve the above-mentioned object,

according to a liquid crystal cell described in claim 1, a liquid crystal cell comprises two electrode substrates 10 and 20; a band seal 20a interposed between the electrode substrates at the peripheral edges thereof; a plurality of barrier walls 40 clamped in parallel to and disposed apart from each other between the two electrode substrates at the inner peripheral side of the seal to form a plurality of filling portions 50; and a liquid crystal 30 filled in each filling portion between the two electrode substrates through the seal.

[0015]

Through holes 41 and 44 of the plurality of barrier walls are formed to communicate each adjacent pair of the two filling portions of a plurality of filling portions. When the smectic liquid crystal in the softened state are filled by vacuum in the individual filling portions between the two electrode substrates of a liquid crystal cell thus constructed, because the space between the two electrode substrates is kept invariable by the individual barrier walls, although the liquid crystals are shrunk by the temperature, the two electrode substrates can be not deformed, so that the vacuum is generated in the individual filling portions.

[0016]

However, as described above, because the individual

through holes are formed in the individual barrier walls, the liquid crystals in adjacent two the individual through the barrier walls pass through the individual through holes of the individual barrier walls and flow to each other, and the vacuum is damped. Further, as described above, although smectic liquid crystals in the individual filling portions are shrunk in the volume, because the space between the two electrode substrates is kept invariable by the individual barrier walls, the volume of bobbles around the inner surface of the seal is increased by the vacuum. That is, because the space between the two electrode substrates is kept invariable, the volume of bobbles around the inner surface of the seal is increased by the vacuum shrinkage amount of the liquid crystals and damps the vacuum.

[0017]

Accordingly, the vacuum is smoothly damped in the individual filling portions and generation of linear bubbles can be prevented in advance in the display area of the liquid crystals. Here, according to claim 2, in the liquid crystal cell described in claim 1, the individual through holes may be formed in the individual barrier walls around an inner wall of one of the two electrode substrates.

[0018]

Further, according to claim 3, a liquid crystal cell comprises two electrode substrates 10 and 20; a band seal

20a interposed between the electrode substrates at the peripheral edges thereof; a plurality of barrier walls 40 clamped in parallel to and disposed apart from each other between the two electrode substrates at the inner peripheral side of the seal to form a plurality of filling portions 50; and a liquid crystal 30 filled in each filling portion between the two electrode substrates through the seal.

[0019]

In orientation films 14 and 26 facing the plurality of barrier walls and between end surfaces 42 and 43 of the plurality of barrier walls facing these orientation films, when one electrode substrate is formed, one of the two electrode substrates that is a recess formed in the inner surface is formed as through holes 41 and 44 for communicating the adjoining two of a plurality of filling portions.

[0020]

In this way, although the through holes are formed as a recess of its inner surface when one of the two electrode substrates is formed, it is possible to obtain the same functions and effects as the invention described in claim 1. Further, according to claim 4,in the liquid crystal cell described in any one of claims 1 to 3, the liquid crystal is a smectic liquid crystal and the individual through holes are formed to damp the vacuums in a plurality of filling

portions caused by the volume shrinkage of a smectic liquid crystal.

[0021]

Therefore, it is possible to enhance the functions and effects of the invention described in any one of claims 1 to 3. Further, according to claim 5, in the liquid crystal cell described in any one of claims 1 to 3, the liquid crystal is a smectic liquid crystal and when the smectic liquid crystal is filled up, a plurality of through holes have an opening shape to prevent the disturbance and stagnation of the flow of liquid crystal flowing to the individual through holes.

[0022]

Therefore, after filling the smectic liquid crystal, it is possible to prevent the defects such as the orientation defect of the smectic liquid crystal or the separation of the liquid crystal layer. Further, according to claim 6, in the liquid crystal cell described in any one of claims 1 to 5, at least one of the two electrode substrates is provided with orientation films 14 and 26 which are oriented in a one-axis direction as an inner surface thereof; and a plurality of barrier walls are extended to a one axis orientation direction of the orientation films between the two electrode substrates.

[0023]

Accordingly, it is possible to secure the strength of a phase structure of the liquid crystals and thus it is possible to obtain the functions and effects of the invention described in any one of claims 1 to 5 while securing good display. Further, according to claim 7, the liquid crystal cell comprises a first electrode substrate 10; a second electrode substrate 20 which is opposite to the first electrode substrate and in which a plurality of color filter layers 22 and a plurality of black mask layers 23 are alternatively arranged; a band seal 20a interposed between the first electrode substrate and the second electrode substrate at the peripheral edges thereof; a plurality of barrier walls 40 clamped between the first electrode substrate and the second electrode substrate to be perpendicular to a plurality of color filter layers in the vicinity of the inner circumference of the seal and forming a plurality of filling portions 50 between the first electrode substrate and the second electrode substrate to be arranged apart from and parallel to each other; and a liquid crystal 30 filled in the individual filling portions through the seal between the first electrode substrate and the second electrode substrate.

[0024]

The individual recesses formed in the inner wall of the second substrate corresponding to regions between the

adjoining two of a plurality of color filter layers are formed as through holes 41 and 44 for communicating the adjoining two of a plurality of filling portions. In this way, although one of the two electrode substrates comprises a color filter layer and a black mask layer, as described above, as a through hole is formed as a recess formed in the inner wall of the second electrode substrate corresponding to the region between the respective two color filter layers, it is possible to obtain the functions and effects similar with the invention described claim 1.

[0025]

Further, according to claim 8, in the liquid crystal cell described in claim 7, the liquid crystal is a smectic liquid crystal and the individual through holes are formed to damp the vacuums in a plurality of filling portions caused by the volume shrinkage of a smectic liquid crystal. In this way, it is possible to obtain the functions and effects similar with the invention described claim 4.

[0026]

Further, according to claim 9, in the liquid crystal cell described in claim 7, The liquid crystal cell according to claim 1, wherein the liquid crystal is a smectic liquid crystal and when the smectic liquid crystal is filled up, a plurality of through holes have an opening shape to prevent the disturbance and stagnation of the flow of liquid crystal

flowing to the individual through holes. In this way, it is possible to obtain the functions and effects similar with the invention described claim 5.

[0027]

Further, according to claim 10, in the liquid crystal cell described in any one claims 7 to 9, at least one of the first and second electrode substrates is provided with orientation films 14 and 26 which are oriented in a one-axis direction as an inner wall thereof; and a plurality of barrier walls are extended to a one-axis orientation direction of the orientation films between the first and second electrode substrates.

[0028]

In this way, it is possible to obtain the functions and effects substantially similar with the invention described claim 6.

[0029]

[Description of the Embodiments]

A first embodiment of the present invention will be described with reference to Figs. 1 to 11.

(First Embodiment)

Figs. 1 to 3 show a first embodiment of a liquid crystal cell according to the present invention. The liquid crystal cell is provided with a lower electrode substrate 10 and an upper electrode substrate 20, between which a smectic

liquid crystal 30 is disposed together with a plurality of barrier walls 40 on the inner side of a band seal 20a (as referred to Fig. 7). Here, the smectic liquid crystal 30 is exemplified by a ferroelectric liquid crystal (FLC) or an anti-ferroelectric liquid crystal (AFLC). On the other hand, the smectic liquid crystal 30 may be replaced by a liquid crystal having similar viscosity characteristics such as a liquid crystal having a high viscosity at the room temperature.

[0030]

The lower electrode substrate 10 is constructed by forming a plurality of metal electrodes 2, a plurality of transparent electrodes 13 and an orientation film 14 in this order on the inner surface of a transparent substrate 11. Here, each metal electrode 2 is formed between a back face of the widthwise central portion of the corresponding transparent electrode 13 and the inner surface of the transparent substrate 11 in the longitudinal direction of the corresponding transparent electrode 13. In this way, each metal electrode 2 lowers the internal resistance of each corresponding transparent electrode 13. Here, the orientation film 14 is omitted from Fig. 1. The electrode substrate 10 corresponds to a scanning electrode substrate.

[0031]

On the other hand, the upper electrode substrate 20 is

constructed by forming a plurality of color filter layers 22, a plurality of black mask layers 23, an over coat layer 24, a plurality of transparent electrodes 25, and an orientation film 26 in this order on the inner surface of a transparent substrate 21. Here, the plurality of color filter layers 22 and the plurality of black mask layers 23 are alternately formed to be in parallel to each other along the inner surface of the transparent substrate 21. Each transparent electrode 25 faces the corresponding color filter layer 22 through the over coat layer 24 and extends along the corresponding color filter layer 22.

[0032]

The plurality of transparent electrodes 25 are arranged to extend at a right angle with respect to the plurality of transparent electrodes 13 to construct a plurality of matrix pixels together with the smectic liquid crystal 30. Here, the over coat layer 24 and the orientation film 26 are omitted from Fig. 1. The electrode substrate 20 corresponds to a signal electrode substrate. Each barrier wall 40 faces each corresponding metal electrode 12 through the widthwise central portion of each corresponding transparent electrode 13 and extends in a stripe shape in the longitudinal direction of the metal electrode 12. Here, each barrier wall 40 has the same width as that of each corresponding metal electrode 12.

[0033]

As a result, the plurality of barrier walls 40 are closely clamped between the two electrode substrates 10 and 20 to form a plurality of filling portions 50 to keep an equal space between the two electrode substrates 10 and 20 and to enhance the resistance to vibration and shock as the liquid crystal cell. On the other hand, each barrier wall 40 is provided, as shown in Fig. 3, with a through hole 41 which is formed along the region between the two of the color filter layers 22 and in the back face 42 of each barrier wall 40 over the inner face (as located on the side of the smectic liquid crystal 30) of the orientation film 14.

[0034]

As a result, the through holes 41 are formed in the number corresponding to that of the regions between the individual color filter layers 22 and in the widthwise direction of the barrier walls to communicate between the two filling portions 50 located on the two sides of the barrier walls. A process for manufacturing the liquid crystal cell thus constructed will be described with reference to Figs. 4 and 5.

[0035]

At a lower electrode substrate forming step S1 of Fig. 4, the lower electrode substrate 10 thus constructed is formed. Next, an upper electrode substrate forming step S2

will be described with reference to Figs. 4 and 5. First of all, at a black mask forming step S21 of Fig. 5, the plurality of black mask layers 23 are formed in parallel at a predetermined space on the inner surface of the transparent substrate 21.

[0036]

Next, at a color filter layer forming step S22, the plurality of color filter layers 22 are formed on the inner surface of the transparent substrate 21 individually between the adjoining two of the plurality of black mask layers 23 and in the longitudinal direction of the black mask layers 23. After this, at an over coat forming step S23, the over coat layer 24 is formed on the inner surface of the transparent substrate 21 through the plurality of color filter layers 22 and the plurality of black mask layers 23.

[0037]

Then, at a transparent electrode forming step S24, each transparent electrode 25 is so formed along each corresponding color filter layer 22 as to face the color filter layer 22 through the over coat layer 24. After this, at an orientation film forming step S25, the orientation film 26 is formed on the over coat layer 24 through the individual transparent electrodes 25.

[0038]

After the end of this upper electrode substrate forming

step S2, at a barrier wall forming step S3 of Fig. 4, the plurality of barrier walls 40 are formed on the inner surface of the upper electrode substrate 20, as follows. Specifically, a photoresist material is applied to a thickness of about 1.6 microns to the whole inner surface of the upper electrode substrate 20 including the inner surface of the orientation film 26 thereby to form a photoresist film. Then, this photoresist film is subjected to an exposing/developing treatment to a predetermined pattern (i.e., a pattern corresponding to the plurality of mutually parallel barrier walls 40 and the plurality of mutually parallel metal electrodes 2) by a photolithographic method to form the plurality of barrier walls 40 on the inner surface of the upper electrode substrate 20.

[0039]

At this time, those regions of the resist film, which correspond to the grooves between the adjoining two of the color filter layers 22, are recessed to a depth of the recesses which are formed after the formation of the over coat layer 24. These recesses have a depth ranging from about 0.5 to 1.0 microns although different depending upon the structure of the electrode substrate 20 forming the color filter layers 22, the black mask layers 23, the over coat layer 24, and the transparent electrodes 25.

[0040]

Here in this embodiment: the black mask layers 23 are given a thickness of about 0.2 microns; the color filter layers 22 are given a thickness of about 1.6 microns; the over coat layer 24 is given a thickness of about 1.2 microns; and the transparent electrodes 25 are given a thickness of about 2,000 angstroms. Next, the inner surface of the orientation film 14 of the lower electrode substrate 10 is subjected to a rubbing treatment at a rubbing step S4, and the inner surface of the orientation film 26 of the upper electrode substrate 20 is subjected to a rubbing treatment at a rubbing step S5 through the plurality of barrier walls 40. Here, the direction to rub the two orientation films 14 and 26 regulates the orientation direction of the smectic liquid crystal 30 when the two electrode substrates 10 and 20 are overlapped.

[0041]

At these rubbing steps, the rubbing directions of the individual orientation films 14 and 26 are desired to be in parallel to the longitudinal direction of the individual barrier walls 40 and either in the same direction or in the opposite directions, as will be reasoned in the following. As has already been described with reference to Figs. 9 and 10, the bubbles are linearly produced in the longitudinal direction of the barrier walls 40 at the widthwise central portion of the individual filling portions 50. As described

above, moreover, these linear bubbles are thought to appear at the widthwise centers of the individual filling portions 50, because vacuums are established in the individual filling portions 50 by the volume shrinkage of the smectic liquid crystal in the individual filling portions 50 and because a force to attract the smectic liquid crystal toward the barrier walls 40 is established by the excellent wettability between the smectic liquid crystal and the barrier walls 40.

[0042]

As a result, liquid crystal layers 31 of the smectic liquid crystal 30 are formed in parallel in the longitudinal direction of the barrier walls 40, as shown in Fig. 6(a), when the inner surface of the orientation film 26 is rubbed in the direction (as indicated by arrow A) perpendicular to the longitudinal direction of the barrier walls 40. Furthermore, the smectic liquid crystal 30 is characterized to be easily separated by the liquid crystal layers 31 so that the linear bubbles are likely to appear when the filling portions 50 are evacuated.

[0043]

On the other hand, when the inner surface of the orientation film 26 is rubbed in a direction (as indicated by arrow B) in parallel with the longitudinal direction of the barrier walls 40, as shown in Fig. 6(b), the liquid

crystal layers 31 of the smectic liquid crystal 30 are formed in a direction perpendicular to the longitudinal direction of the barrier walls 40. This makes it hard to cause the separation in the liquid crystal layers 31. This means that the liquid crystal layers 31 are strong against the vacuums in the filling portions 50.

[0044]

Therefore, as described above, the directions to rub the individual orientation films 14 and 26 are desired to be in parallel with the longitudinal direction of the individual barrier walls 40 and either in the same direction or in the opposite directions. At a next seal printing step S6, the peripheral edge portion of the inner surface of the electrode substrate 10 is printed with a thermoset resin in a U-shape to form the seal 20a. Simultaneously with this, a liquid crystal filling port is also formed.

[0045]

After this, at a superposing step S7, the two electrode substrates 10 and 20 are superposed through the seal 20a and the plurality of barrier walls 40. In this case, the superposition of the two electrode substrates 10 and 20 is so performed that the individual orientation directions of the two orientation films 14 and 26 may be in parallel with the longitudinal direction of the individual barrier walls 40. Next, the treatment of a heating and pressing step S8

is taken in the following manner.

[0046]

The two electrode substrates 10 and 20 thus superposed are arranged in a heating and pressing apparatus 60, as shown in Fig. 4, and the inside of this apparatus 60 is then heated by a heater. After this, a nitrogen gas N^2 is pumped from a gas supply pipe 63 to the inside of an air bag 62 (made of silicone rubber) which is mounted on the inner face of an upper wall 61 of the heating and pressing apparatus 60. According to this pumping operation, the air bag 62 is inflated to press the two electrode substrates 10 and 20 uniformly on a table plate 64. At this time, the pressure is 0.9 Kg/cm^2, and the heating temperature is 190℃. In this state, the two electrode substrates 10 and 20 are held for 60 minutes. After this, the inside of the heating and pressing apparatus 60 is returned to the room temperature and the atmospheric pressure by a slow cooling.

[0047]

According to the treatment of the heating and pressing step S8 thus far described, the height of the individual barrier walls 40 (as corresponding to the space between the two electrode substrates 10 and 20) is crushed to about 0.1 to 0.2 microns. Considering that the metal electrodes 12 have the aforementioned thickness of about 0.3 microns, the thickness of the liquid crystal layers of the smectic liquid

crystal 30, i.e., the space between the two electrode substrates 10 and 20 is finally about 1.7 microns.

[0048]

Here, the method of adjusting the crush of the heights of the individual barrier walls 40 is exemplified by a method of adjusting the hardness of the individual barrier walls 40 and by a method of adjusting the force to crush the individual barrier walls 40. The former is exemplified by adjusting the pre-baking temperature and time, whereas the latter is exemplified by adjusting the pressure to be applied to the two electrode substrates 10 and 20. In the heating and pressing treatment thus described, on the basis of the difference between the thickness of the individual color filter layers 22 and the thickness of the individual black mask layers 23, the upper faces of the individual barrier walls 40 rise into the grooved regions between the individual two color filter layers 22 at the portions corresponding to the grooved regions, as shown in Fig. 3.

[0049]

Accordingly, those portions of the back faces 42 of the individual barrier walls 40, which correspond to the aforementioned individual raised portions, are recessed according to the rises of the individual raised portions. As a result, the individual recessed portions of the back faces 42 of the individual barrier walls 40 are formed as

the individual through holes 41 between the back faces 42 and the inner surface of the orientation film 14. Therefore, for the individual barrier walls 40, the individual through holes 41 communicate between the two filling portions 50 which are located on the two sides of the corresponding barrier walls 40.

[0050]

Here, the individual barrier walls 40 are crushed in their heights to about 0.1 to 0.2 microns, as described above, so that the through holes 41 have an internal diameter ranging from 0.3 to 0.9 microns. If the flows of the smectic liquid crystal into the individual through holes 41 are turbulent or stagnant at a filling step of the smectic liquid crystal to be described later, this smectic liquid crystal is caused to have an orientation defect. Therefore, the internal diameter of the individual through holes 41 may be sized to prevent the aforementioned disturbance and stagnation of the flows.

[0051]

Next, at a liquid crystal filling step S9, the two electrode substrates 10 and 20 thus heated and pressed are contained and heated in a vacuum container at about 20℃. In this state, the inside of the vacuum container is evacuated for about 2 hours to evacuate the region between the two electrode substrates 10 and 20, and a smectic liquid

crystal is dropped to a portion near the liquid crystal filling port of one of the two electrode substrates 10 and 20. Accordingly, the smectic liquid crystal softens to plug the liquid crystal filling port of the seal 20a.

[0052]

In this state, the inside of the vacuum container is returned to the atmospheric pressure, and then this atmospheric pressure is kept for 12 hours. At this state, according to the differential pressure established between the region in and the outside of the two electrode substrates 10 and 20, the smectic liquid crystal is sucked and filled into the individual filling portions 50 between the two electrode substrates 10 and 20 through the liquid crystal filling port of the seal 20a. Thus, the filling step of the smectic liquid crystal is ended.

[0053]

After this, at a sealing step S10, the liquid crystal filling port of the seal 20a is plugged. As a result, the manufacture of the liquid crystal cell is ended. Here, at the aforementioned liquid crystal filling step S9, it is difficult to completely eliminate the bubbles which are produced in the individual filling portions 50 between the two electrode substrates 10 and 20. The bubbles are left in the vicinity of the inner surface of the seal 20a, as indicated by a reference numeral P in Fig. 7.

[0054]

Here, in this embodiment, the volume change of the smectic liquid crystal filled into the individual filling portions 50, with the temperature of the smectic liquid crystal follows a graph L of Fig. 11. The liquid crystal phase series of the smectic liquid crystal are as follows, or vice versa:

$$\mathrm{Cry} \rightarrow \mathrm{SmC_k}^{\circ} \xrightarrow{(71.8°C)} \mathrm{SmC}^{\circ} \xrightarrow{(73.6°C)} \mathrm{SmA} \xrightarrow{(92.6°C)} \mathrm{ISO}$$

[0055]

As a result, the smectic liquid crystal filled at 120□ has a volume of 0.958 cm^3 /g in the ISO phase (i.e., isotropic phase) and shrinks by about 8% at the room temperature of 25□ and by about 10% at -20□. However, even if the liquid crystal cell thus manufactured is left at a temperature as cold as -20□ for 100 hours, the residual region of the bubbles P in the vicinity of the seal 20a becomes wide, but no linear bubble is produced in the display area of the liquid crystal cell. This causes no display defect in the liquid crystal cell.

[0056]

The reasons for this phenomenon will be described. First of all, the aforementioned volume shrinkage occurs in the smectic liquid crystal in the individual filling portions 50 between the two electrode substrates 10 and 20,

but the through holes 41 are formed between the individual barrier walls 40 and the orientation film 14, as described above. As a result, the liquid crystal portions in the two filling portions 50 adjoining each other through the barrier walls 40 flow to and from each other through the individual through holes 41 of the barrier walls 40 to damp the vacuums which are established in the individual filling portions 50.

[0057]

Secondly, when the smectic liquid crystal in the individual filling portions 50 shrinks in its volume, the volume of the bubbles P in the vicinity of the inner surface of the seal 20a increases with the aforementioned vacuum because the space between the two electrode substrates 10 and 20 is kept invariable by the individual barrier walls 40. This means that the volume of the bubbles P will increase by the volume shrinkage of the smectic liquid crystal to damp the vacuums because the space between the two electrode substrates 10 and 20 is invariable.

[0058]

It can be concluded that the vacuums in the individual filling portions 50 are so satisfactory damped on the basis of the first and second phenomena described above and that the establishment of the linear bubbles in the display area of the liquid crystal cell can be prevented in advance.

(Second Embodiment)

Fig. 8 shows a second embodiment of the liquid crystal cell according to the present invention.

[0059]

In this second embodiment, individual through holes 44 are formed in place of the individual through holes 41, as described in connection with the first embodiment, between the upper electrode substrate 20 and the individual barrier walls 40. Here, the individual through holes 44 are formed in the following manner. When the upper electrode substrate 20 is formed at the upper electrode substrate forming step S2, as described in the first embodiment, those portions of the orientation film 26 and the over coat layer 24, which correspond to the groove-shaped regions of the two adjoining color filter layers 22, are recessed into the individual groove-shaped regions, as shown in Fig. 8.

[0060]

Unlike the first embodiment, in this second embodiment, the plurality of barrier walls 40 are formed by a method similar to the aforementioned one on the inner surface of the orientation film 14 of the lower electrode substrate 10 which is formed at the lower electrode substrate forming step S1 of Fig. 4. In this case, since the orientation film 14 of the lower electrode substrate 10 is flat, the two upper and lower end faces of the individual barrier walls 40 are generally in parallel as a whole, as shown in Fig. 8.

[0061]

After this, the treatments of the two rubbing steps S4 and S5 and the seal printing step S6 of Fig. 4 are taken substantially like the first embodiment. After these steps, at the superposing step S7 of Fig. 4, the two electrode substrates 10 and 20 are so superposed as in the first embodiment that the orientation directions of the two orientation films 14 and 26 are in parallel with the longitudinal direction of the individual barrier walls 40.

[0062]

As a result, the individual through holes 44 are formed between the orientation film 26 and the surfaces 43 of the individual barrier walls 40, as shown in Fig. 8. Next, the treatment of the heating and pressing step S8 of Fig. 4 is made. At this heating and pressing step S8, the two electrode substrates 10 and 20 are heated and pressed, as described in connection with the first embodiment, but the two upper and lower end faces 41 and 43 of the individual barrier walls 40 are in parallel as a whole, and the orientation film 14 of the electrode substrate 10 is also flat.

[0063]

Therefore, even after the heating and pressing treatment, the orientation film 26 is kept to have the recesses, as shown in Fig. 8. As a result, the individual

through holes 44 are formed between the electrode substrate 20 and the individual barrier walls 40, as shown in Fig. 8. The individual through holes 44 thus formed communicate between the two filling portions 50 through the barrier walls 40 like the individual through holes 41 described in connection with the first embodiment.

[0064]

As a result, operations and effects similar to those of the first embodiment can be achieved. In the practice of the present invention, the liquid crystal cell may not use any color filter layer. In this modification, recesses corresponding to the through holes 41 or 44 of the first or second embodiment are formed by setting the thickness of the individual transparent electrodes of one of the two electrode substrates of the liquid crystal cell to such a value as to form those through holes.

[0065]

Furthermore, upon the practice of the present invention, the liquid crystal should not be limited to the smectic liquid crystal but can adopt a liquid crystal which has a viscosity characteristic to the temperature like that of the smectic liquid crystal.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a perspective view illustrating a portion of

a liquid crystal cell of a first embodiment according to the present invention.

[Fig. 2]

Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1.

[Fig. 3]

Fig. 3 is a cross-sectional view taken along line 3-3 of Fig. 1.

[Fig. 4]

Fig. 4 is a flow chart illustrating a method of manufacturing the liquid crystal cell of Fig. 1.

[Fig. 5]

Fig. 5 is a flow chart illustrating a detailed process of an upper electrode substrate forming step of Fig. 4.

[Fig. 6]

Figs. 6(a) and 6(b) are schematic cross-sectional views of portions of liquid crystal cells illustrating phase structures of smectic liquid crystals of the case in which an orientation film of the first embodiment is rubbed in directions of arrows A and B.

[Fig. 7]

Fig. 7 is a partial top plan view illustrating the state of bubbles produced in the vicinity of the inner circumference of a seal at a liquid crystal filling step of Fig. 4, with the upper electrode substrate being removed.

[Fig. 8]

Fig. 8 is a partial cross-sectional view illustrating a liquid crystal cell of a second embodiment according to the present invention.

[Fig. 9]

Fig. 9 is a top plan view illustrating a conventional liquid crystal cell.

[Fig. 10]

Fig. 10 is a cross-sectional view of a portion taken along line 10-10 of Fig. 9.

[Fig. 11]

Fig. 11 is a graph plotting a relation between a volume and a temperature of a smectic liquid crystal in a conventional liquid crystal cell.

[Reference Numerals]

10, 20: electrode substrate
14, 26: orientation film
20a: seal
22: color filter layer
23: black mask layer
30: smectic liquid crystal
40: barrier wall
41, 44: through hole